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EFFECTS OF RIFLE ZERO AND SIZE OF SHOT GROUP ON MARKSMANSHIP SCORES

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This research sought to determine the relative contributions of two factors on marksmanship performance. One factor, shot group size, is an index of a soldier's ability to apply the fundamentals of rifle marksmanship (aiming, trigger squeeze, etc.). The other factor, rifle zero, is an index of how well a soldier can place his or her shot group in reference to an aiming point (e.g., center of a target). Our objective was to determine whether one of the factors was more responsible for poor marksmanship performance than the other.

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INTRODUCTION

The US Army Vice Chief of Staff (now Chairman of the Joint Chiefs) stated in an 11 December 1980 memorandum on marksmanship, "If the fighting Army does nothing else, we must be able to hit our targets. Conversely, if we do all other things right, but fail to hit and kill targets, we shall lose." Unfortunately, as the Basic Rifle Marksmanship Trainer's Guide (1982) points out, the marksmanskip skill of the American military rifleman has gone from the impressive feats accomplished by the early frontiersmen to the unacceptably low level of shooting skills exhibited by today's American soldier. One major reason offered for today's poor shooting performance is the competing demands for training time from many other important tasks of modern day soldiering.

Given the importance of rifle marksmanship and the limited time allotted to the training of this skill in a soldier's basic training, it would seem to be of tremendous value to delineate specific areas of marksmanship which are contributing to the poor performance. If a small number of factors can be isolated which contribute highly to the soldier's inability to hit targets, these areas could be given more attention, hopefully, without having to restructure the entire marksmanship training program.

This study was conducted with the objective of determining the relative contributions of two major factors which play a part in a soldier's success in

hitting 25-meter scaled silhouette targets. These factors were shot group size and rifle zero. Shot group size is an index of a soldier's ability to apply the fundamentals of shooting. Rifle zero is an index of how close a soldier can place a shot group to target center.

Another consideration in this research was the effect that different scoring systems have on discrimination of good shooters from poor shooters. Three scoring systems were considered. One was the currently-used 5-cm. diameter circle with its four scoring rings allowing 10, 9, 8 or 7 points per shot (See Figure 1). With this system, any bullet falling outside the 5-cm. diameter circle is assigned a score of zero points. This seemed an inappropriately large drop (7 to 0) as a result of only one centimenter deviation from the center of the target. It was expected that by enlarging the area in which a bullet could receive a score, reliability of overall scores from one firing to another would be increased over that offered by the present scoring system. In other words, by assigning values to more of the bullets (those that fall outside of the 5-cm. diameter circle) more of the true variance in bullet hole locations can be incorporated into the score and reliability should be increased from one shooting exercise to another.

To test this prediction, one of the new scoring systems assigned a value of 120 points for any bullet falling within a 1-cm. diameter circle about the center of the target, 110 points for a bullet falling within the area between 1 and 2 cm. in diameter, 100 points for a bullet falling within the area between 2 and 3 cm. in diameter, and so on. Therefore any bullet falling within the area of a 12-cm. diameter circle about the target center was given a score of at least 10 points.

Both the original FORSCOM-scoring system and the 12-cm. diameter scoring system described above provide scores that are linearly related to the distance from the target center. This does not correspond to the area for the different rings which, of course, is related to the square of the distance from the target center. For example, the area of the 2-cm. ring is three times that of the 1-cm bull's eye.

The second new scoring system assigned scores that were inversely proportional to the area of a circle bounded by the target ring in which they landed. Bullets landing within a 1-cm. diameter circle were assigned a value of 144 points. Any other bullets falling within 12 cm. of the target center were assigned scores by dividing 144 by the square of their distance (in cm.) from the target center. This formula resulted in scores between 1 and 144 being assigned to individual bullets with much higher scores for bullets closer to the target center. For each of the three scoring methods that were compared, overall scores consisted of the summed values for the 10 rounds fired at each of the targets.

METHOD

SUBJECTS

The 57 subjects used in this study were drawn from a larger group of 120 soldiers who composed A and B companies of the 3/7th Infantry Battalion of the 197th Infantry Brigade. The 63 soldiers who were not included for purposes of analysis were eliminated because they either : (1) were NCO's (about 1/3 of all

those not used), or (2) had more or less than the necessary 40 rounds on their targets. Since there are a number of reasons, other than shooting ability, which can result in targets with an incorrect number of bullet holes (e.g., incorrect number of rounds loaded in the magazine, weapon malfunction, firing on incorrect targets, etc.) these targets were eliminated to ensure that shooting ability was the analyzed variable.

PROCEDURE

The data used in this study were the locations of each of 40 bullets fired by each of the 57 soldiers in two FORSCOM targets used in a unit marksmanship training exercise. This exercise was conducted from 15 March to 19 March 1982 at Ft. Benning, Georgia. The targets used in this analysis were shot on the first day of this period from a supported fox-hole position at a range of 25 meters. Prior to firing the FORSCOM competitive exercise, the soldiers had received a day of refresher basic rifle marksmanship training (aiming, position, trigger-squeeze, and dry-fire exercises), 10 rounds of ball and dummy, and a 10-round grouping exercise shot on a 25-meter scaled silhouette zero target.

For this exercise, two FORSCOM targets were used with two 10-round shot groups being fired at each of them. The first 10 rounds for each target were fired at the zeroing target located at the top center of the sheet (see FORSCOM target in Figure 1). After determining and making appropriate changes in zero, the second 10 rounds were fired with two rounds at each of the five silhouette targets. This second group was scored for purposes of comparison with the record score to be fired later. For the second FORSCOM target, the same procedure was followed (10 rounds at a zeroing target, zero adjustments, 10

rounds at five silhouette targets). Scores on the second set of silhouette targets were the record fire scores. In summary, this entire procedure resulted in 40 rounds being fired and two 10-round scored targets per individual.

ANALYSES

Horizontal and vertical distances of each bullet hole were measured in millimeters from the bullet hole center to the target center by using a grid overlay. The result was an X (horizontal) and a Y (vertical) coordinate for each of the 40 bullet holes. These 40 bullet holes were categorized into the following four subgroups. Target 1 and Target 3 groups were those shots fired at the two zeroing targets and Target 2 and Target 4 were the two groups fired at the silhouette targets. Target 2 and Target 4 will be referred to as practice firing and record firing, respectively. Shot group size and rifle zero were computed for each 10-round subgroup as well as for the 40-round total by incorporating the bullet coordinates into appropriate trigonometric formulae. These variables were computed for A and B Companies separately and combined.

RESULTS AND DISCUSSION

SHOT GROUP SIZE

Shot group size is an index of a soldier's ability to apply the fundamentals of rifle marksmanship. For the purposes of this analysis, shot group size was defined as the mean radial distance of each bullet hole from the center of the shot group. The average shot group size for each target is shown below for each company, separately and combined.

TABLE 1 *

Shot Group Sizes For Each Target
And Each Company

TARGET	COMPANY A	COMPANY B	COMBINED
1	1.73 (0.66)	1.69 (0.50)	1.70 (0.57)
2	1.81 (0.76)	1.80 (0.56)	1.80 (0.64)
3	1.75 (0.36)	1.86 (0.62)	1.82 (0.53)
4	1.94 (0.56)	1.94 (0.75)	1.94 (0.67)
Total	1.81 (0.42)	1.82 (0.51)	1.82 (0.47)

* Shot group size in centimeters. Numbers in parentheses are standard deviations

As can be seen in Table 1, shot group size was relatively consistent across the four 10-round groups (ranging from 1.70 cm. to 1.94 cm.). The positive correlation between shot group sizes of the scored portions of the two targets was very significant ($r = .534$; $p < .001$).

The finding that all of these soldiers were, on the average, able to apply the fundamentals of shooting well enough to keep their shot groups confined within a 3.88-cm. diameter circle is consistent with previous research (Osborne, Morey, and Smith; 1980). In an investigation of the accuracy of the M-16 rifle, Osborne, et al (1980) found that "...the typical M-16 rifle issued to basic trainees is capable of firing a shot group size of 2.1 cm. By applying correct shooting fundamentals, this shot group can be adjusted to fall within a 4-cm. circle." Although for the Osborne, et al (1980) study, shot group size was defined as "the largest center-to-center distance measured on pairs of the three bullet holes," the soldiers in the present study were able, on the average, to place a 10-round shot group within a circle of similar diameter. The implications of this finding are that, on the average, one would expect these soldiers to attain scores in the 60's and middle 70's on the FORSCOM exercise. As will be shown, this was not the case due to inadequate skill in placing shots on target.

ZERO OF THE WEAPON

Weapon zero can be considered an index of how well the individual can place his/her shot group on target. Individual and average scores on this variable were computed by calculating the center of the shot group (centroid) and then calculating the radial distance of the centroid from the center of the target. Table 2 shows the mean and median radial distances in centimeters that the centroids were divergent from the centers of each of the four targets.

TABLE 2

Mean And Median Distance Of Zeros From Target Centers

	MEAN ZERO	MEDIAN ZERO
Target 1	2.4 * (1.6)	2.0
Target 2	1.8 (1.1)	1.5
Target 3	1.7 (1.3)	1.4
Target 4	1.3 (0.8)	1.4
Total	1.8 (0.7)	1.7

* Radial distance from shot group center to target center in centimeters. Numbers in parentheses are standard deviations.

Adjustments were made in rifle zero after shooting Target 1 and Target 3. This adjustment may account for the larger differences between the means for Targets 1 and 2 and between the means for Targets 3 and 4 than between means for Targets 2 and 3. In any case, a steady improvement in the zero of the weapons (decreased divergence from center of target) is realized as the soldiers worked through the four ten-round exercises.

Weapon zero (radial distance from shot group center to target center) on Target 2 did not correlate with weapon zero on Target 4 ($r = .054$; n.s.). Rezeroing weapons after Target 3 undoubtedly was a factor in this absence of relationship. However, those shooters who had excellent zeroes on Target 2 were no more apt to have good zeros on Target 4 than shooters who had poor zeros on Target 2 and this suggests that, at best, only a rudimentary skill at zeroing weapons exists among these shooters.

EFFECTS OF SHOT GROUP SIZE AND ZERO ON SCORES

Most soldiers in this study had sufficiently tight shot groups to hit within a 4-cm. diameter circle. On the FORSCOM silhouette target this corresponds to the "8-ring." By assuming a perfect zero (overlaying the scoring rings such that the center of the target aligns with the center of the shot group), a significant increase in both the practice and the record score is realized as shown in Table 3.

TABLE 3

Mean And Median Scores As Scored By Eye And Assuming Perfect Zeros

	REAL SCORE		ASSUMING PERFECT ZERO	
	MEAN	MEDIAN	MEAN	MEDIAN
PRACTICE	51.7	54.8	71.0	76.0
RECORD	57.6	58.0	70.3	72.3

By making this adjustment for a perfect zero, average score for practice and record increased by an average of 17 points. This would suggest that the quality of the zero on their weapons has an important effect on the soldier's ability to hit the FORSCOM targets above and beyond their ability to apply the fundamentals of basic rifle marksmanship.

Regression analyses were done to assess the relative contributions of rifle zero and shot group size in predicting the scores on the practice and record targets (see Table 4 for the zero-order correlations and R-Squared values). For the practice target, rifle zero was found to account for a much larger portion of the variance (R-Squared = .56) than did shot group size (R-Squared = .24), regardless of the order in which they were entered into the regression equation. For the record target, zero was found to account for more variance (R-Squared = .55) than did shot group size (R-Squared = .21), when zero was entered first in the equation. When shot group size was entered first in the equation, the portion of variance it accounted for increased (R-Squared = .45) making shot group size the most salient predictor. Zero was found to contribute a somewhat smaller amount of variance over and above shot group size (R-Squared = .31).

TABLE 4

Correlations And Multiple R's Of Zero And Shot Group Size

	PRACTICE			RECORD		
	r	R2 (a)	R2 (b)	r	R2 (a)	R2 (b)
ZERO	-.75	.56	.57	-.74	.55	.31
SHOT GROUP SIZE	-.48	.23	.24	-.67	.45	.21

(a) When entered first into the equation.
(b) When entered second in to the equation.

These results show that both shot group size and rifle zero are important factors in determining scores on these marksmanship targets. This leads to a "chicken or the egg" situation when one seeks to determine which is most important. Does shot group size come to be important only after a weapon has been zeroed or does zero come to be important only after shot group size has been reduced to useful limits? The results presented above suggest that zero was the most important factor with respect to shooting decrements. These soldiers were already applying shooting fundamentals well enough to have fairly tight shot groups; however, a large number of their bullets were falling outside of the 5-cm. diameter circle used to assign scores. This may reflect their inability to consistently place shot groups well enough to have obtained a good weapon zero.

A question related to the relationship between shot group size and rifle zero is: Are those individuals who attain tighter shot groups the same individuals that have better zeros? That is, are there some individuals who are just better shooters? Correlations between shot group size and zero show that there is no relationship between the two for the practice target ($r = -.01$; n.s.). For the record target the relationship between shot group size and zero was significant ($r = .318$; $p < .01$). These correlations suggest that both zeroing attempts were needed to develop or at least restore skill at zeroing.

Only then did the expected relationship between marksmanship ability and quality of rifle zero appear. Although the implications of these correlations are tentative at this point, it is possible that allowing soldiers to shoot two or three zeroing sequences (even with a reduced number of rounds per sequence) before shooting a scored exercise would allow for even further improvement in zero of their weapons.

ANALYSIS OF PATTERNS IN SHOT GROUPS

Although there was no correlation between radial distances of shot group centroids from practice to record targets, it is inappropriate to say that zeros did not relate between practice and record targets without considering the signed deviations about the bulls'eye of these centroids. In other words, shooters may have been consistently in one or the other quadrant from practice to record fire and this would not necessarily have produced a positive correlation for a radial distance measure. Additional analyses were conducted to determine whether there were consistent patterns in the directions that bullet holes were deviating from target centers from practice to record fire. Examination of correlation coefficients of horizontal deviations between practice and record targets ($r = .15$; n.s.) as well as vertical deviations between the two targets ($r = .13$; n.s.) suggest that there were no consistent patterns across the two targets even when signed deviations are considered.

In an attempt to determine whether horizontal or vertical zero errors were more important in causing reductions in marksmanship scores, horizontal and vertical deviations were separately included in regression analyses. Deviations along horizontal and vertical axes were converted to absolute values to achieve comparability with the unsigned radial distances which had predicted scores for each target.

For the practice target, both horizontal and vertical deviations accounted for substantial amounts of unique variance in predicting score (R-Squared = .38 and .37, respectively). However, neither of these directional deviations could be considered to be of more importance than the other for predicting score ($t(54) = .576$; n.s.). For the record score target, vertical deviations accounted for a large portion of variance (R-Squared = .68) with horizontal deviation adding very little unique variance (R-Squared = .03). For this target, there was substantially more deviation along the vertical axis than along the horizontal axis ($t(54) = 3.52$; $p < .01$). Zero-order correlations between the absolute deviations also showed that, despite larger vertical deviations, there was less consistency along the vertical axis ($r = .13$; n.s.) than along the horizontal axis ($r = .22$; $p < .05$) between the two scored targets.

This finding of an inconsistency along the vertical axis may have been a result of inconsistent aiming (sight picture) along the vertical plane. Given the visual cues presented by the sights, it would appear to be an easier task to consistently place the sights on the target horizontally. The front post is horizontally symmetrical and the target is bounded on either side by the symmetrical curved guards on the front sight. Both factors help ensure that the sight post is placed on the horizontal center of the target. In terms of the vertical plane, it would appear to be a more difficult task to consistently place the top of the sight post on the vertical center of the target because of the absence of corresponding symmetrical vertical bracketing visual cues. Less vertical consistency may also be partly due to the fact that the portion of the target (scaled 250-meter target) that is below the top of the sight post is

obscured by the sight post. Finally, adjustment of the front sight is more difficult on the M16 than adjustment of the rear sight. One or more of these three factors probably account for the larger variance found in the vertical plane.

UTILITY OF EXPANDED SCORING SYSTEMS

A more reliable scoring system would lead to more consistent ordering of shooters from one target to another. The correlation between the scores on the two scored targets, using the standard 5 cm. diameter circle as the area in which a score could be assigned to a bullet, was non-significant ($r = .158$). That is, score on one of the targets had very little relationship to the score on the other target. Low reliability associated with small target area seemed like a possible explanation and problem.

For the second scoring system, where scores were assigned for all bullets landing within 6 cm. of target center in any direction, score of the practice target was found to be significantly related to score on the record target ($r = .225$; $p = .05$). That is, by extending rings out to pick up a number of additional bullet holes that would otherwise be counted as zeros (those bullet holes falling outside the 5 cm. diameter circle) one gained some predictability of how well a soldier would shoot on the record target by observing the score on the practice target.

For the third scoring system, scores were inversely proportional to the area of a circle bounded by the target ring where the bullet fell. This system also extended the scored area out to a 12-cm. diameter circle, but this system assigned much higher weights to bullets at the center than at the edge. For

this system, prediction of the score on the record target from score on the practice target was found to be unreliable ($r = .078$; n.s.).

In summary, for two of the three scoring systems investigated, score on the practice target was found to be unrelated to score on the record target. That is, knowing how well a soldier shot at one point in time was found to tell little about how well the soldier would shoot at another point in time. The scoring system which did result in significantly related scores across the two shooting exercises, was a system which simply enlarged the scored portion of the target, hence picking up more of the individual variance in bullet-hole locations.

However, this should not be considered to be the last word on different scoring systems. The large differences in rifle zero between the practice and record fire targets, probably accounts for the very small correlations between practice and record scores on all three scoring systems. Only when the rifle was well zeroed and shot groups were very small would the third system that maximized scores for near "bull's eyes" lead to more reliable measurement of marksmanship performance. This system might improve reliability of scores in competitions with match-quality shooters

As previously stated, the scored portion of each target consisted of firing two rounds at each of five silhouette targets. Therefore, score is based on a summed total of the scores on ten rounds (see FORSCOM target, Figure 1). In order to compare different methods for scoring shooting performance, without effects of a zero change, correlations were computed between scores on the top three silhouettes with scores on the bottom two silhouettes for both the practice and the record targets.

For the standard scoring system (5 cm. diameter circle with scores for individual bullets ranging from 10 to 7 points) the correlation between the top three and the bottom two silhouettes was very significant ($r = .58$; $p < .001$) for the practice target and only slightly less significant for the record target ($r = .36$; $p = .003$).

Significant relationships were likewise found between the top three and the bottom two silhouettes for the 12 cm. scoring system. For this scoring system the relationships were slightly higher than those found with the standard scoring system as shown by the correlations for the practice target ($r = .66$; $p < .001$) and for the record target ($r = .44$; $p < .001$). For the 12 cm. diameter inverse square scoring system the relationships were also significant for the practice and record targets ($r = .32$; $p < .01$; $r = .32$; $p < .01$, respectively) although not as strong as that elicited by the other systems. Again, the drop in reliability for the third scoring system probably reflects the fact that only weapons with excellent zeros would benefit from the higher weighting of scores for bullets falling near the target center.

These findings indicate that the soldiers in this study were shooting consistently enough that shooting performance on a subgroup of the targets could be used to predict shooting performance on another subgroup of the targets with a reasonable degree of certainty. This was true for the existing scoring system and for a scoring system that included more of the bullets fired on target. When a delay and opportunity for sight changes occurred between individuals' shooting, correlations dropped sharply and only the larger target showed a significant correlation between target scores. These results show the two major findings of the study. Targets with larger scoring areas provide more reliable

discrimination between good and poor shooters and ability to zero weapons accurately is poor in Army shooters even after completion of basic rifle training.

CONCLUSIONS AND RECOMMENDATIONS

The significant correlations for shot group size between practice and record fire and the absence of such correlations for absolute and signed locations of shot group centers, suggest that problems with zero are the main detriments to higher scores on the FORSCOM marksmanship exercise. Many factors including the perception of target center, position, focus of the eye, light conditions pressure on the barrel, tend to be held constant during the firing of a single group of bullets and thus do not influence the size of the shot group. These factors may not be constant between shot groups, however, and the result is a large variance in the centers of the shot groups for the same individual, resulting in much confusion regarding proper sight adjustments for his weapon.

A poorly zeroed weapon greatly complicates training of the same marksmanship fundamentals that are needed to achieve a good zero. If a good zero could be placed on the trainee's weapon before he receives it, and zeroing training were left to a later stage of marksmanship training after marksmanship fundamentals were better mastered and when he had become more accustomed to firing the weapon, many fewer marksmanship training problems would be expected.

This raises questions about individual differences in sight settings to zero the same weapon. Individual differences in rifle zeroes exist, but they seem to have much more influence in competitive marksmanship settings. It has been estimated (A. Osborne, personal communication) that 15 of 20 trainees

with the capability of mastering shooting fundamentals, would be able to fire accurately with the same weapon zeroed once for all 20.

In summary, the results of this study suggest that these soldiers' inability to accurately zero their weapons; whether as a function of lack of training, lack of practice, or both; is a major contributor to their subsequent inability to hit targets. The existing scoring system for the FORSCOM competition target is adequate to distinguish between shooters but could be improved by extending the number of scoring rings outward.

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